served in the holotype, and only known specimen, though the opening is present according to a communication received by the senior author from Dr. Bassler. The deltoids are rather elongated and there appears to be about 40 marginal plates. The theca is elongated and is subpentagonal in outline according to the description of the form. *C. oklahomae* differs from *C. americanus* in having a short, rounded theca, short deltoids, short broad ambulacra, and a reduced number of marginal plates.

C. oklahomae differs from European species in having elongated ambulacral covering plates, reduced number of marginals, shorter deltoids and more than five covering plates for the anus.

Occurrence.—Lower Bromide formation, Ordovician; exposure in the east bank of Spring Creek a tributary of Hickory Creek, Criner Hills, some 7 miles southwest of Ardmore, Okla.

Types.—Holotype and one paratype to be deposited in the U. S. National Museum.

REFERENCES

All references are listed in Bassler and Moodey, *Bibliographic and faunal index of Paleozoic Pelmatozoan* echinoderms, Geol. Soc. Amer. Spec. Pap. 45, p. 199. 1943.

ENTOMOLOGY.—*Three new species of* Culicoides *from Texas (Diptera: Heleidae).*

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(Received July 12, 1955)

In early 1953 it was definitely established that the virus disease of sheep known as bluetongue is present and is occasionally epizootic in the southwestern United States. In South Africa, where bluetongue has caused severe losses to sheep raisers and has been studied intensively for several decades, the only proved vectors are biting midges of the genus *Culicoides*. Drs. D. A. Price and W. T. Hardy, veterinarians of the Texas Agricultural Experiment Station at Sonora, have produced bluetongue infections in sheep experimentally by injections of macerated *Culicoides variipennis* (Coquillett) caught in a light trap on the station where an outbreak of the disease was in course (Journ. Amer. Vet. Med. Assoc. **124:** 255–258. 1954).

In preparation for anticipated further studies on the epidemiology of bluetongue in America, including the determination of the vector species and studies on their biology and control, a survey was begun in May 1953 to determine the distribution of the species of *Culicoides* in the bluetongue area of Texas. Descriptions of three new species taken on the surveys are presented here, in order to make their names available to other workers. The types are deposited in the U. S. National Museum in Washington.

I am greatly indebted to the personnel of the Kerrville laboratory of the Agricultural Research Service for their assistance in the survey.

Culicoides neopulicaris, n.sp.

Fig. 1

♀. Length 1.25 mm, wing 1.13 by 0.5 mm.

Head dark brown, eyes contiguous, bare. Antennae with flagellar segments in proportion of 20:18:18:18:18:18:18:18:20:22:25:28:45, distal sensory tufts on segments 3, 11–15. Palpal segments (Fig. 1, b) in proportion of 10:22:34:13:10 third segment moderately swollen in middle with numerous spoon-shaped sensillae borne on extensive concavity distal to middle of segment.

Mesonotum dark brown, the dorsal surface with yellowish gray pruinosity, with more or less of an indication of a broad median paler gray band from humeral pits to prescutellar sensory depression, the long hairs mixed yellowish and dark brown. Scutellum dark brown, with four strong blackish bristles; pleura very dark brown. Legs uniformly dark brown, becoming somewhat paler on tarsi; hind tibial comb of six long subequal bristles.

Wing (Fig. 1, a) with anterior radial cells complete; costa 0.6 as long as wing. Macrotrichia fairly numerous on distal half of wing and in cell M4 and anal cell. Wing predominantly whitish, the dark markings quite limited, forming essentially three broken transverse bands of spots as figured. The first dark costal spot halfway between wing base and crossvein r-m and extending from costa only across base of media; second costal spot covering distal half of first radial cell, not extending into cell R5; third costal spot just past apex of costa, hourglass-shaped, the

anterior part wider, the posterior part extending only to the fold above vein M1. Small, but quite distinct dark spots also at bases of medial and mediocubital forks, at apices of veins M1, M2, M3–4 and Cu1, the latter two extending on veins M3–4 and Cu1 to their bases, the spot at end of M3–4 extending forward nearly across cell M2 just before tip, and a separate dark spot near apex of cell M1 at level of spot in cell M2. An isolated dark spot in middle of pale area in cell M4 and a dark spot at half the length of anal vein extending back and widening distad into a large dark area along caudal margin extending nearly to vein Cu1. Halteres whitish.

Abdomen dull blackish; spermathecae two, subequal, ovoid, slightly tapered to the ducts.

Male genitalia (Fig. 1, c–d). Ninth sternum with shallow mesal excavation, the posterior membrane bare; ninth tergum distally rounded, with well-developed median lobe, the apicolateral processes practically absent. Basistyles with mesal margins straight, each bearing a dense patch of strong spines towards base, dorsal roots well developed, ventral roots very small; dististyles slender, apices not expanded, slightly incurved. Aedeagus with basal arch rounded, extending to a little more than half of total length, the distal half broad and tapering to a broadly rounded tip. Parameres bent at basal third, the mesal margins approximated on middle third, the apices narrowed to slender, pubescent tips.

Holotype female (type no. 62363, U.S.N.M.), allotype, Kerrville, Tex., June 15, 1953, L. J. Bottimer (light trap). Paratypes: 9 males, 69 females, same data except dates June 13 to October 20, 1953. Other material: 4 females, Ciudad Valles, San Luis Potosí, Mexico, December 1, 1944, B. Brookman (light trap).

This species is closely related to *yukonensis* Hoffman from Alaska and the Yukon, as well as to the Palearctic species *pulicaris* (Linnaeus) and *punctatus* (Meigen), all having, in addition to the pale apex of the second radial cell, a small isolated dark spot in the mediocubital fork. *C. neopulicaris* can be readily separated from the related species, however, by its smaller size, less hairy wings invariably with small but very definite dark spots, and lack of the dark area in cell R5 behind the dark spot over the first radial cell. *C. punctatus* and *yukonensis* differ in having the apices of veins M1 and M2 pale and *punctatus* has a well-developed mesonotal pattern. The obsolete apicolateral processes of the ninth tergite, and the broad apex of the aedeagus will separate the males of *neopulicarus* from those of the other species.

Several males of this species have been received from Dr. Luis Vargas, of the Instituto de Salubridad y Enfermedades Tropicales in Mexico City. They were taken at Chilpancingo in Guerrero, and Dr. Vargas informs me that the species is very abundant in the basin of the River Balsas.

Culicoides bottimeri, n.sp.

Fig. 2

Female—Length 0.9 mm, wing 0.85 by 0.43 mm.

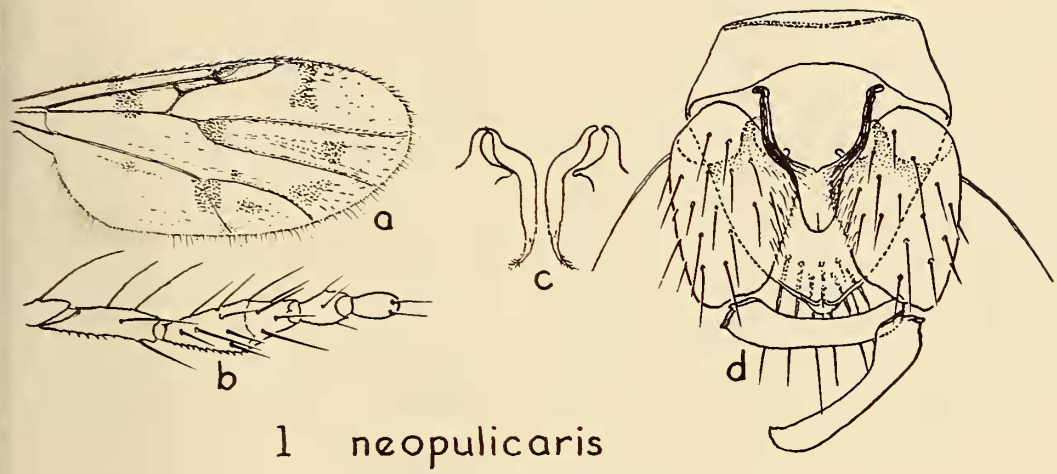
Head dark brown; eyes bare, slightly separated. Antennae with flagellar segments in proportion of 16:11:11:12:12:12:13:13:20:20:20:22:30, distal sensory tufts on segments three to ten inclusive. Palpi (Fig. 2, a) short, segments in proportion of 8:15:35:12:12, third segment markedly swollen, with a broad, shallow, sensory pit.

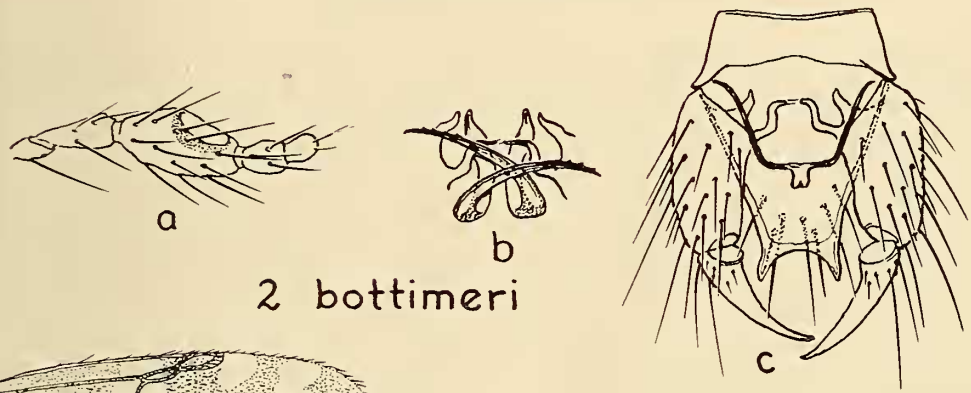
Mesonotum uniformly subshining dark brown, without trace of pruinose spots or vittae, the long and rather numerous brown hairs not restricted to rows. Scutellum dark brown, with two long, submedian, and a few very small, brown hairs. Pleura concolorous with mesonotum. Legs uniformly brownish, slightly paler than thorax, hind tibiae each with five long yellow bristles in apical comb.

Wing uniformly gray, without trace of light or dark spots. Costa ending at 0.53 of wing length; anterior radial cells short and broad, the adjacent radial veins considerably swollen. Wing appearing very hairy, the long macrotrichia dense and extending to wing base behind the anterior media.

Abdomen brownish; spermathecae two, slightly unequal, oval, bases of the ducts not sclerotized.

Male genitalia (Fig. 2, b–c).—Ninth sternum with very shallow, broad, mesal excavation, the posterior membrane spiculate; ninth tergum markedly tapered, with long triangular apicolateral processes, the posterior margin between them semicircular. Basistyles moderately slender and tapering, the dorsal roots short and broad, the ventral roots long and sinuate with broad bases, their apices joined mesad; dististyles slightly incurved and tapering to very slender, pointed tips. Aedeagus with very narrow anterior arms forming a broad and deep, trapezoidal,





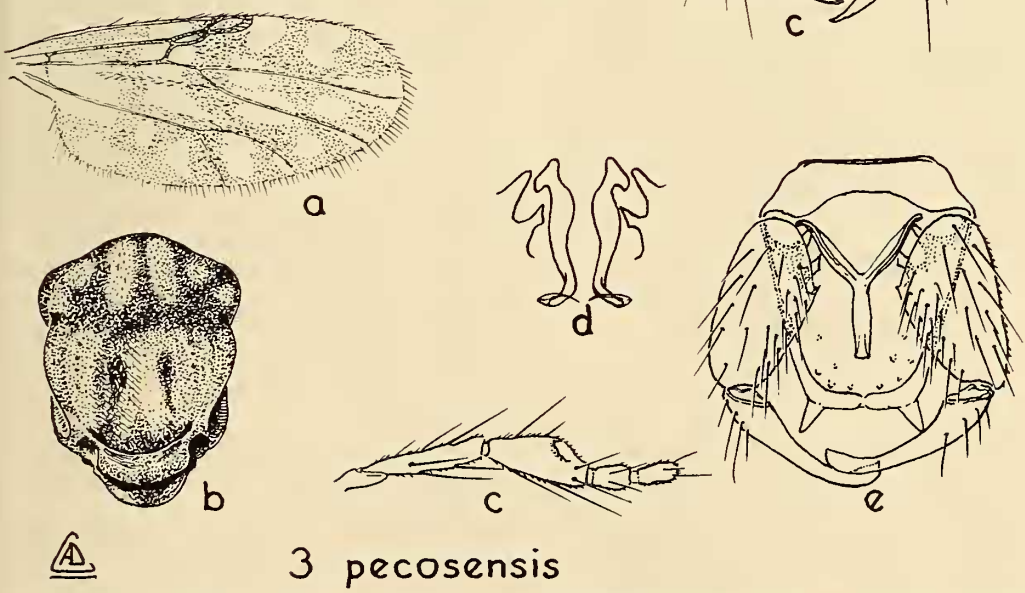


Fig. 1.—*Culicoides neopulicaris:* a, Female wing; b. female palpus; c, male parameres; d, male genitalia, parameres removed.
Fig. 2.—*Culicoides bottimeri:* a, Female palpus; b, male parameres; c, male genitalia, parameres removed.
Fig. 3.—*Culicoides pecosensis:* a, Female wing; b, mesonotal pattern; c, female palpus; d, male parameres; e, male genitalia.
Drawings by Arthur D. Cushman.

basal arch, the distal point short and truncate in ventral view but with a small triangular apex turned ventrocephalad. Parameres with bases not knoblike, the stout stems obtusely bent midway, the distal half of each paramere abruptly recurved ventrocephalad in the form of a curved, heavily sclerotized saberform blade with the pointed apex faintly serrate on the outer margin.

Holotype female (type no. 62364, U.S.N.M.), Kerrville, Tex., June 15, 1953, L. J. Bottimer (light trap). Allotype, same data except July 11, 1953. Paratypes: 12 males, 73 females, same data except dates June 13 to September 27, 1953. I take pleasure in naming this species for Lawrence J. Bottimer, of Kerrville, whose enthusiastic and careful assistance made this study possible.

This species is very closely related to the European species, *cunctans* (Winnertz) and *pumilus* (Winnertz), both of which also have the plain, hairy wings and undecorated, subshining, brown mesonotum. The male genitalia of *bottimeri* are most nearly like those of *cunctans*, but according to Edwards (British Bloodsucking Flies, p. 141, 1939) that species has the apicolateral processes slenderer, the ventral roots slenderer and not joined mesad, the aedeagus with the anterior arch not so broad caudad and the parameres with the recurved blades much shorter and not serrate. This species superficially resembles the North American species *stonei* James and *brookmani* Wirth in its plain brown mesonotum and unmarked hairy wings, but the other two species have a duller mesonotum with very faintly indicated vittae and their female spermathecae and male genitalia indicate that they belong to entirely unrelated groups.

Culicoides pecosensis, n.sp.

Fig. 3

Female.—Length 1.2 mm, wing 1.25 by 0.52 mm.

Head and its appendages dark brown; eyes slightly separated, bare. Antennae with flagellar segments in proportion of 20:18:18:18:18:18:18:18:30:32:32:32:44, distal sensory tufts on segments 3–5, 7–9, 11–14. Palpal segments (Fig. 3, c) in proportion of 12:36:36:15:15, third segment moderately swollen with a moderately deep, broadly open, sensory pit.

Mesonotum (Fig. 3, b) dark brown with a prominent pattern of pruinose gray spots placed much as in *arboricola* Root and Hoffman, but never so prominent. These spots consist essentially of six pairs of rounded spots in two series of three pairs each, the submedian pair of each series larger and more elongate, the anterior pair extending forward between the humeral pits, the posterior pair covering the broad flattened prescutellar area, the two lateral pairs of each series small and rounded. Scutellum dark brown with gray pruinosity, with four long brown bristles. Pleura dark brown. Legs dark brown, with broad subapical bands on all femora and broad subbasal bands on all tibiae and broad apical band on hind tibia, pale yellowish; 5 or 6 long bristles in hind tibial comb.

Wing (Fig. 3, a) with anterior radial cells complete, costa to 0.55 of wing length; macrotrichia long and dense, covering nearly entire wing. Anterior wing margin with three intensely dark areas the second including apex of first and all of second radial cell. Wing with prominent pale spots as follows: Four spots on costal margin, the first just beyond humeral crossvein and extending beyond base of anterior media, the third beyond tip of second radial cell covering half the breadth of cell R5 and the fourth more or less chevron-shaped with point basad about halfway between the preceding spot and wing tip and extending to the fold before vein M1. A pale spot straddling vein M1 at level of end of costa and a similar one straddling vein M2 a little nearer its apex; a small pale round spot at about its own length from wing margin in cell M1 and another larger one very near wing margin in cell M2; a small oval spot in cell M2 just anterior to base of mediocubital fork. Cell M4 with a broad pale band across its middle half; apices of veins M1, M2 and M3-4 broadly pale margined but no trace of pale area on vein Cu1. Two distinct pale spots in apex of anal cell and a larger pale area on basal half of its posterior margin. Haltere pale.

Abdomen blackish; cerci pale; spermathecae two, slightly unequal, ovoid, very slightly tapered to the ducts.

Male genitalia (Fig. 3, d–e).—Ninth sternite with broad shallow excavation, the posterior membrane bare; ninth tergite with large, triangular apicolateral processes. Basistyles with dorsal and ventral roots subequal, simple and pointed; dististyles with apices slender and incurved. Aedeagus with basal arms nearly straight,

heavily sclerotized, about half of total length, the distal portion broad, slightly expanded in middle, with broadly truncated apex. Parameres with prominent basal knobs, the stems slightly swollen and slightly sinuate, gradually tapered to simple distal points which are abruptly bent laterad, then ventrad and then mesad at their apices.

Holotype ♀ (type no. 62365, U.S.N.M.), allotype, 4 male and 20 female paratypes, Sanderson, Terrell County, Tex., August 29, 1953, H. Brundrett (light trap).

Culicoides arboricola Root and Hoffman is closely related but can be readily separated from *pecosensis* by the presence of the pale spot on the apex of wing vein Cu1, the pale band in cell M4 is narrower, the gray pruinose mesonotal pattern is more prominent and the male genitalia have the aedeagus with a rounded basal arch and longer, very slender distal point and the parameres are more swollen in the middle portion. *C. oursairani* Khalaf lacks the mesonotal pattern, the pale wing spots are more reduced in size and the male aedeagus has a low rounded basal arch and slender distal point, the apicolateral processes of the ninth tergite of the male are slenderer and the parameres are much stouter and more sinuate. *C. guttipennis* (Coquillett) and *villosipennis* Root and Hoffman are also related but have much different male genitalia.

LETTERS TO THE EDITOR

Limitations on Rapid Signal Analysis

There are determinable limits to the resolution that can be achieved when a frequency analysis of a signal is made over a brief time interval. The limiting resolution is a function of the least power increment or decrement that can be indicated by the analyzer.

The analyzer should be able to change its indication by at least the smallest detectable power increment during a specified time after sudden onset or removal of the input signal. Thus the rate at which the indication builds up or decays in the analyzer must exceed a limiting value. It is useful to describe this rate by reference to the response time of the analyzer, i.e., the time required to reach substantially steady-state indication after an abrupt change in signal. Because the frequency resolution of an analyzer is directly proportional to the response time, discrimination is sacrificed in the interest of fast response.

The limitations discussed here can be illustrated by reference to a three-dimensional space (see Fig. 1) in which the Cartesian coordinates are frequency, time, and either power or a function of power. The particular problem dealt with here then becomes calculation of a least volume in this space, within which no information about the signal can be found.

The limitations can be illustrated by the familiar properties of a linear series-resonant system, used as a tuned filter to indicate how a particular component of a complex signal fluctuates with time.

Let the observation interval, $\Delta\tau$, be sufficiently large compared with T_0, the undamped natural period of the filter so that phase characteristics can be ignored. Let f_0 be the undamped resonance frequency of the filter. Denote π times the reciprocal of the decrement-per-cycle of the system as Q the "figure of merit."

The smallest discernible change of indicated power is taken as ΔW. Defining a time-attenuation constant α such that, after interruption of the signal, the initial power indication W_0 must decay by $\Delta W \geqslant$

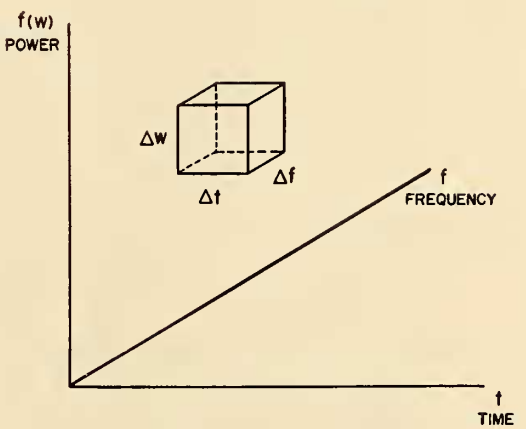


Fig. 1.—Three-dimensional space